HOW TO BUILD

A ONE-FOURTH HORSE POWER

MOTOR OR DYNAMO

By A. E. Watson.

ILLUSTRATED WITH WORKING DRAWINGS.

PRICE, 50 CENTS.

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NO less accurate workmanship is required in the construction of a small dynamo than in one of a larger size. However, in this chapter is described a machine of such size and arrangement of parts as to be within the reach of amateurs' tools, yet capable of continuous and efficient service. It can be used as dynamo or motor, series, shunt, or compound wound, for any potential not exceeding 110 volts. Figures 1 and 2 show the complete machine in side and end elevations.

For convenience the description will be divided as follows:

1. Field magnet and frame.
2. Armature, shaft, and pulley.
3. Bearings.
4. Commutator.
5. Brushes, holders and yoke.
6. Winding.
7. Connections.
8. Testing and using.

The Field Magnet and Frame consists of two cast iron "pole pieces" united by a wrought iron "core." Referring to Figure 3-(b), it will be seen that the castings are apparently alike, but the patterns must be so made that the arms for supporting the

bearings will come on reverse sides, so that when the two are placed facing each other, both long arms will be on the commutator side and both short arms on the pulley side.

Provided with the castings, the holes for the core should be bored out smoothly to two inches in diameter. For doing this the castings may be either bolted to the traveling carriage of a lathe, and a boring bar inserted, or to a face plate, using a rigid inside boring tool. If possible finish with a reamer. Drill, tap and counter-bore for the seven-sixteenths inch screw "a" on the bolt and screw list, Figure 4. The slots at the bottom, which may well have been cored part way, can now be extended through with a hack saw. The core is to be of wrought iron, seven and three-sixteenths inches long, smoothly turned to two inches in diameter. If what commonly known as "cold rolled" steel is available, no turning will be necessary. This quality of steel is very soft and quite as good as wrought iron for magnetic purposes.

Put one pole piece on the core, tighten the clamping screw; drill a one-fourth inch hole through the cast-iron into the steel and drive in a steel pin about three-fourths inch long. These two parts will then be permanently attached. Slip on the other pole piece, see that the protruding arms are parallel, tighten in place, and drill a one-fourth inch hole in the end, so as to be half in the core and half in the pole piece, in the location as shown, and drive in another pin. This method locates the two parts definitely, but allows easy removal of one pole piece for placing the field spool.

The boring of the ends of the arms and the field may now be done. Bolt the structure as now assembled to the carriage of a screw cutting lathe. With a boring bar between

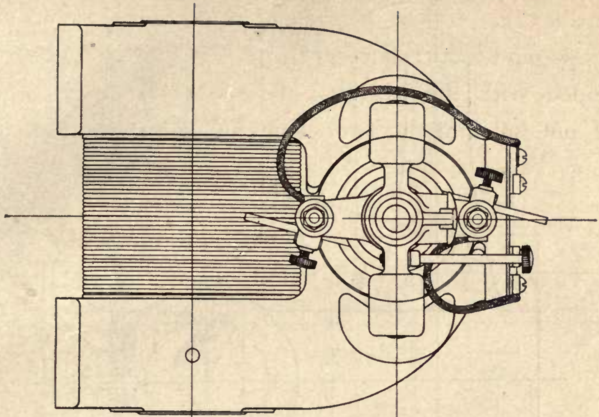

FIGURE 1.

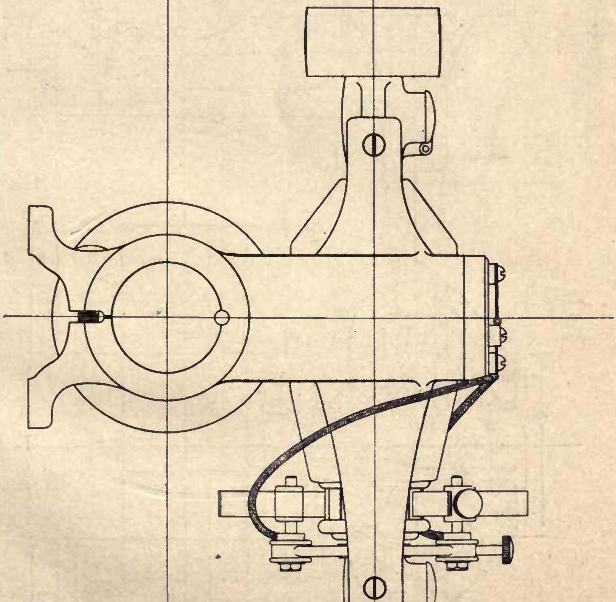

FIGURE 2.

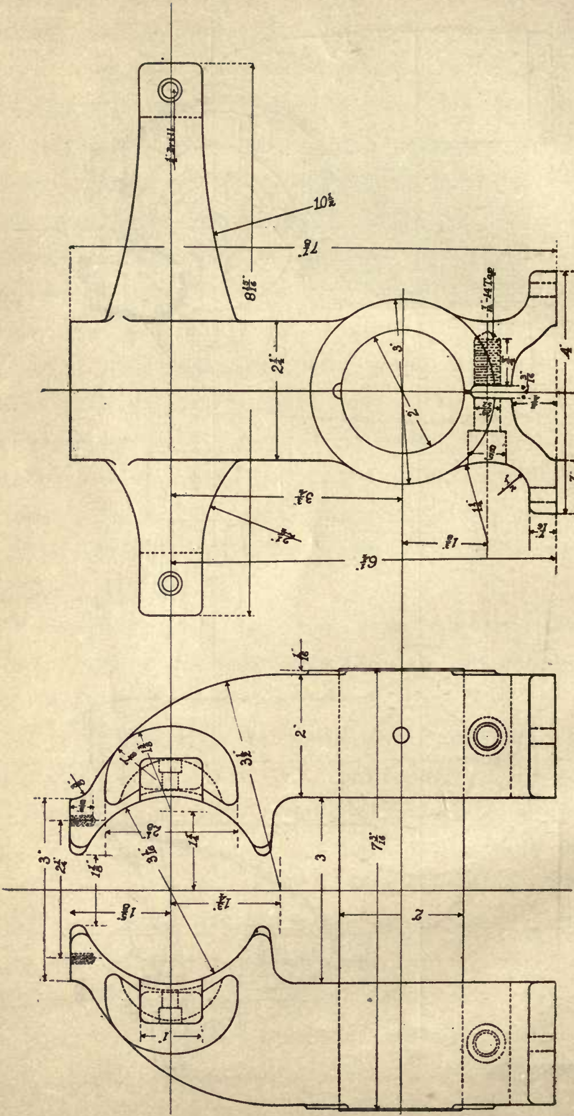

FIGURE 3 (a).

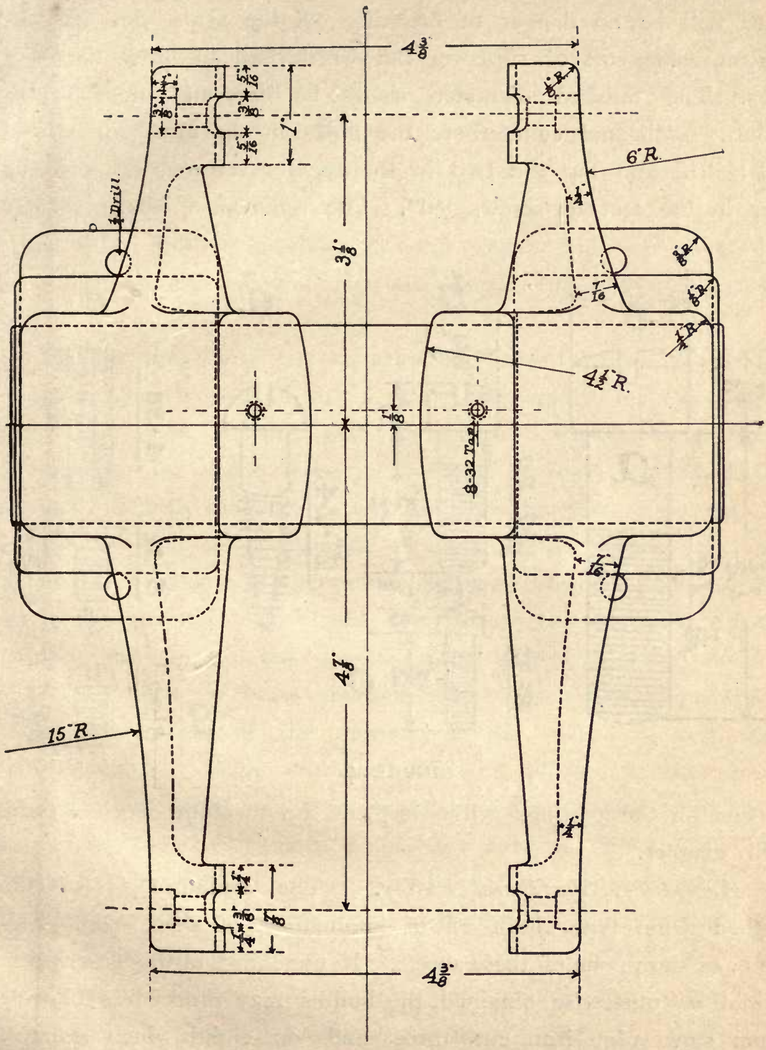

FIGURE 3 (b).

centers, take first a slight chip, at slow feed. If carefully done, there will be no danger of breaking off the arms, but if convenient some sort of supports can be devised to brace the long ones. The finished diameter should be three and one-sixteenths inches. Drill and counterbore the holes in the arms for screws "b"; drill and tap the two in the top for screws "c"; drill the four in the feet for screws "d". The removal of sharp corners

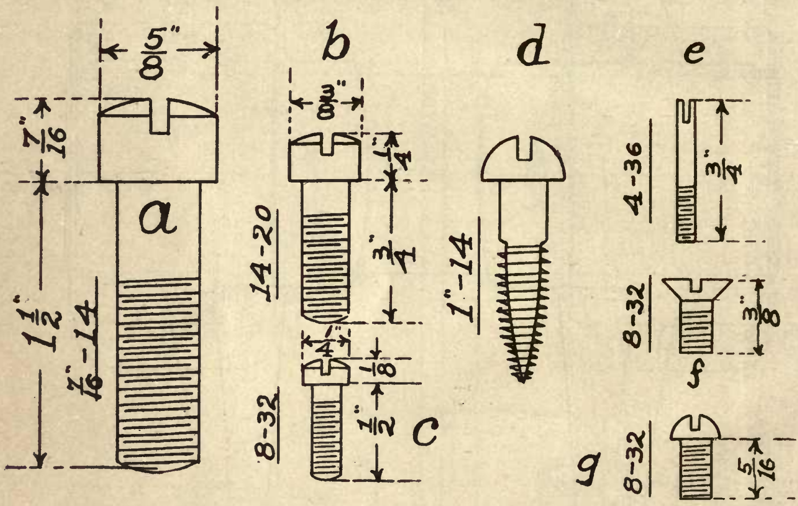

FIGURE 4.

or fins on the castings will complete the machine work on the field magnet.

Armature, Shaft and Pulley. The armature is of the toothed drum type, built up of laminations of sheet iron. Figure 5, *a*, shows one of these sheets. If punchings of this description cannot be otherwise obtained, the builder may proceed as follows: From stove pipe iron cut three and one-eighth inch squares. Enough should be cut to make a thickness two and one-fourth

inches when tightly clamped together. Cut the corners so as to make the sheets octagonal. Clamp them between plates of one-fourth or three-eighths inch iron and drill a five-eighths inch hole as near the center as possible. Put in a short five-eighths inch turned bolt and screw on the nut. Remove the other clamps and turn the mass to a diameter of three inches. Without disturbing the center bolt, put the cylinder thus formed in a milling machine or gear cutter and saw out the the sixteen slots as shown, one-fourth inch wide and three-eighths deep.

Part of the work on the shaft may now be done. Procure a suitable length of cold rolled steel, five-eighths inch in diameter, center it in a lathe, with the aid of a back rest, and turn it, excepting the space three inches long in the centre, to nine-sixteenths inch in diameter. On the ends of that space cut 27 threads per inch for a distance of three-eighths inch. Cast-iron flanges or "heads," for screwing on these threaded portions, are clearly shown at "*b*," Figure 5. Screw one of these tightly in place and slip on the punchings. It will be necessary to put a piece of iron or brass one-fourth inch thick and about three inches long in one of the grooves in the sheets, to keep the teeth matched. With this bar still in place, tightly screw on the other head, using a spanner wrench with pins engaging in the two small holes as shown. By oiling its surface and threads, this may be easily done without allowing the sheets to slide on each other. Replacing the armature in the lathe, it will probably be found that the shaft does not run true; this is due to the fact that sheet iron cannot be procured of an exactly uniform thickness, and the shaft has had to bend to compensate for the difference. With a lever

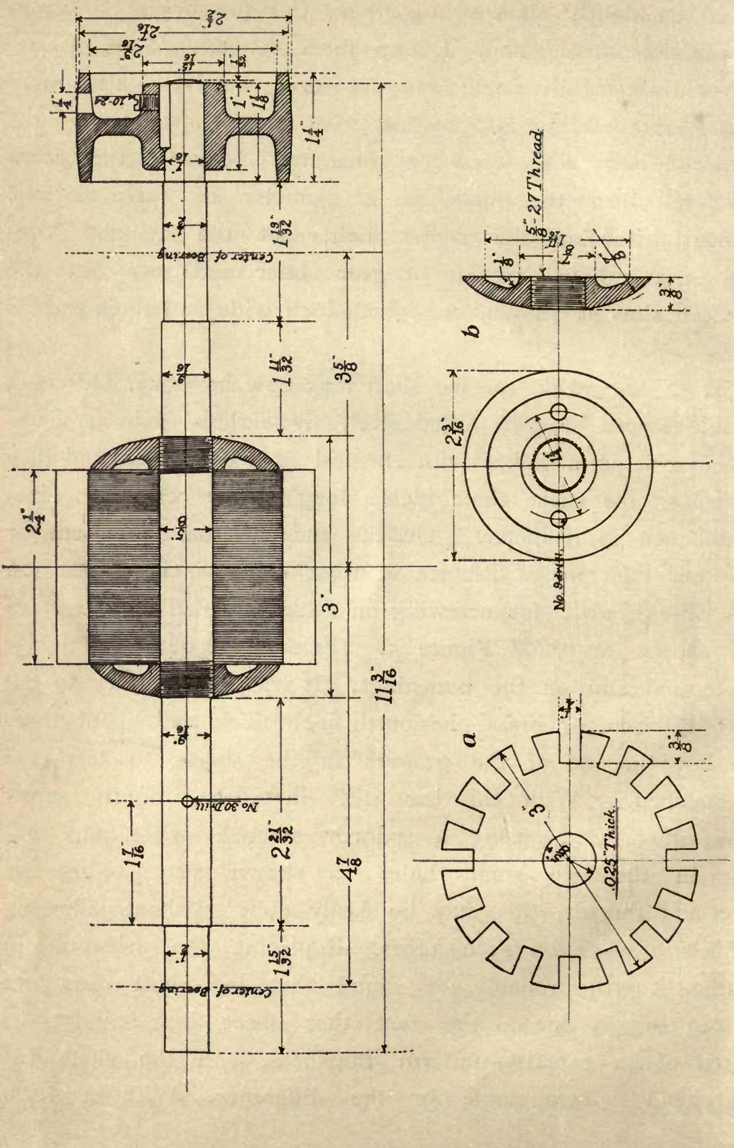
Center of Bearing
No. 30 Drill
Center of Bearing
10-24
5/8"-27 Thread
.025" Thick.
a
b

FIGURE 5.

spring the shaft until it runs true, and complete the turning to the required dimensions. Leave the portions for the bear-

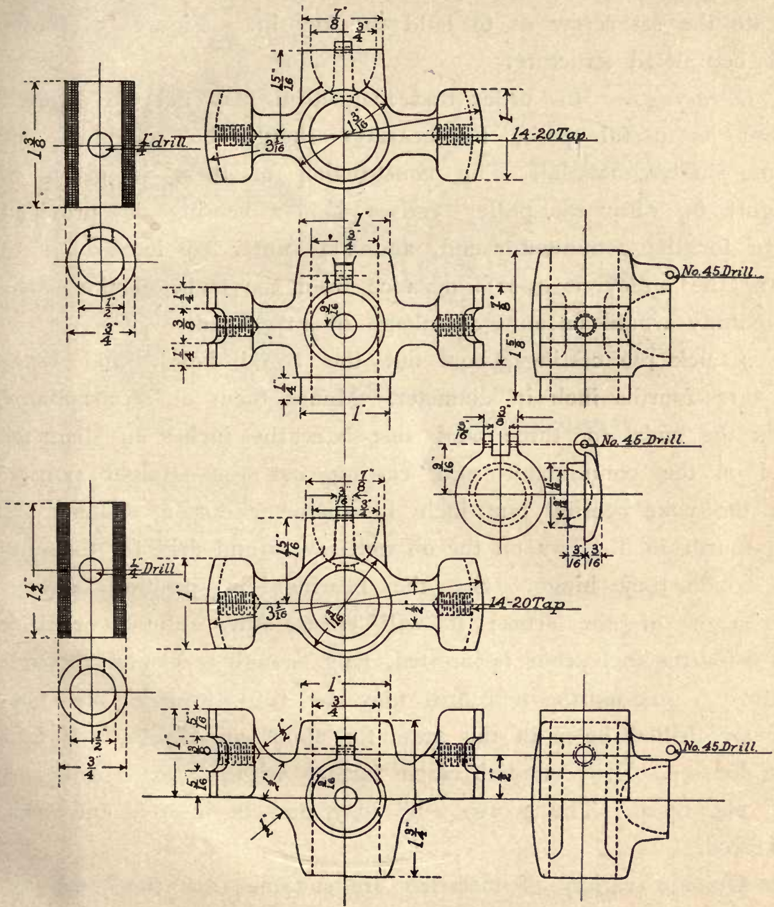

FIGURE 6.

ings about one-hundredth inch large to allow for final fitting. Put in the small pin for holding the commutator in position.

After turning and fitting the pulley, a No. 30 drill may be run in on the end, half in the pulley and half in the shaft. Use a piece of one-eighth inch steel wire for a key and so locate the set screw as to hold the key in. Figure 5 shows the completed structure.

Bearings. In order that magnetism may not be diverted from its useful path, the bearings should be of brass, or some similar material. The construction of these is given in Figure 6. For the pulley end a longer bearing is provided than for the commutator end, and the center so located as to carry the pulley at a safe distance from the ends of the arms. Proximity would encourage leakage of magnetism.

Chuck the castings, bore out the cored holes, and ream to three-fourths inch in diameter. Mount them on an arbor and turn the ends to three and one-sixteenths inches in diameter and on the commutator end casting cut the straight portion for the yoke bearing one inch in diameter for a distance of one-fourth inch. Lay on the oil-well covers and drill for the pins on which they hinge. Set the bearings in position between the ends of the arms; it will ensure their alignment if a three-fourths inch arbor is inserted, long enough to extend through both. A one-fourth inch drill may be run through the previously drilled holes in the arms for about one-eighth inch into the brasses. Drill one-half inch further with a No. 8 drill and tap out 14-20. The screws "b" may now be inserted and arbor removed.

Quite a variety of materials are suitable for the bushings or "linings" for the bearings. Brass, gun metal, graphite, cast iron, babbitt metal and lignum vitae are used. Gun metal is in good favor. Drill out the castings, ream them to one-

half inch in diameter, mount them on an arbor, turn the outside and ends to size. The oil groove may be cut with a round-nosed hand tool. It will be noticed that the linings are

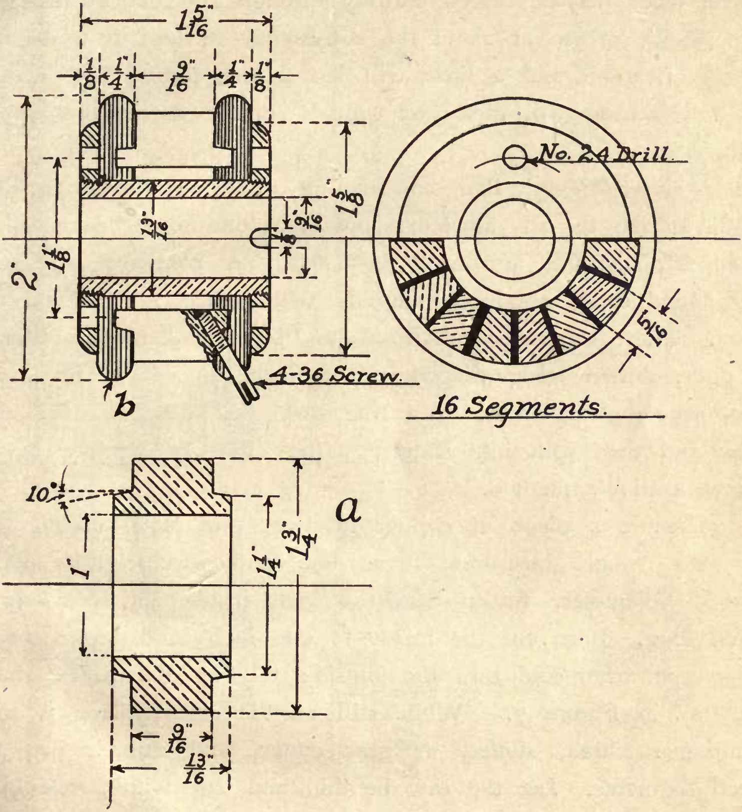

FIGURE 7.

shorter than the castings into which they are to be forced. The purpose is to provide a surface for catching the oil that may be thrown from the shaft while running. Locate the linings so as to bring the armature in center of the field, and

allow about one-sixteenth inch for end motion; then drill through the bottom of the oil-wells and insert short pieces of brass tube. When occasion requires the removal of the bushings, these tubes may be driven entirely through and out of the way.

Thick grease of about the consistency of lard is to be used for lubrication, and a little will last a long time. The warmth of the bearing will melt just enough grease to ensure proper oiling.

Commutator. The construction of a commutator is often a Waterloo to an amateur, but the one here described is compact, durable and well insulated. A comparatively small lathe and easily obtained materials will suffice for its construction. There are sixteen divisions, or "segments," made of smooth copper, drawn wedge-shaped, or of filed castings to fit around into a complete circle; or a ring may be turned to the right size and then split into sixteen parts. The latter may be the more available method.

Procure a piece of copper tube, or gun metal casting, that in the rough measures about one and seven-eighths inches outside diameter, fifteen-sixteenths inch inside, and seven-eighths inch long. Bore out the inside to one inch in diameter, mount it on an arbor and turn the outside to the dimensions shown at "a" in Figure 7. While still on the arbor, place it in a milling machine, slotter, or gear cutter, and saw it into sixteen segments. Let the saw be thin and cut within one-thirty-second inch of the arbor. Fit strips of mica to the saw cuts, then finish cutting the segments apart. File off the burrs and assemble the segments and insulations into a circle. Secure them with a string or rubber band, and prepare the rest of the structure.

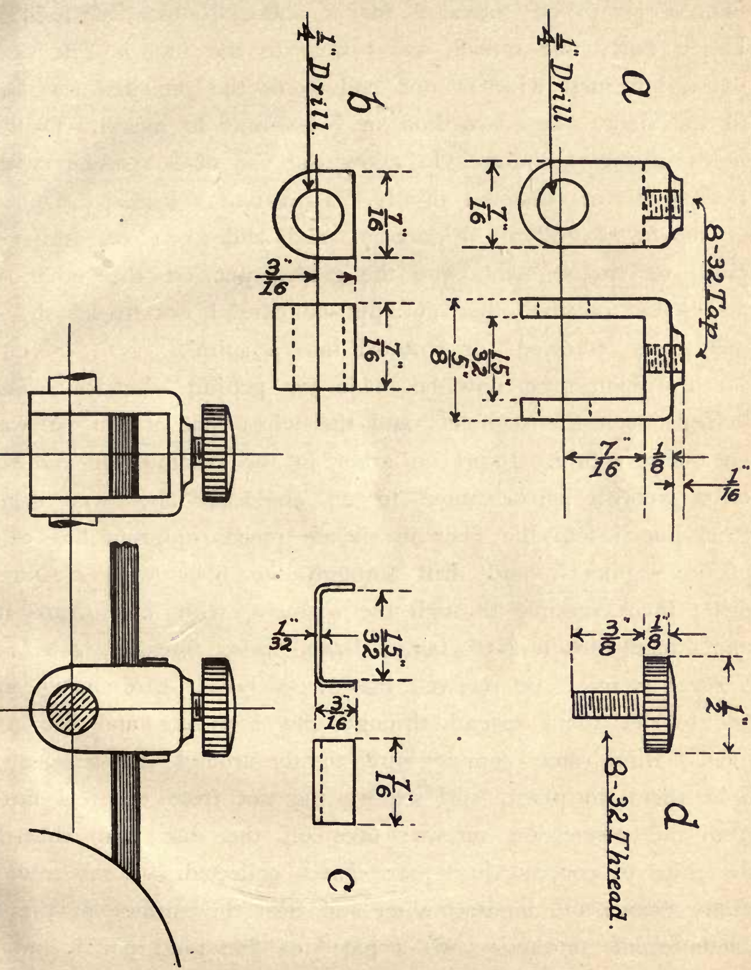
a
¼" Drill.
8-32 Tap
7/16"
15/32"
5/8"
7/16
1/8
1/16"
b
¼" Drill.
7/16"
3/16"
7/16"
c
1/32"
15/32"
3/16"
7/16"
d
1/8"
3/16"
½"
8-32 Thread.

FIGURE 8.

A piece of seamless brass tube, one and three-eighths inches long, three-fourths inch outside and nine-sixteenths inch inside diameter is to be threaded for a short distance at each end. Use a fairly fine thread, say twenty to the inch. File a slot one-eighth inch wide in one end to fit the pin that was located in the shaft. Tap two iron or brass nuts to match. Drill two holes in these thin nuts to allow the use of a spanner wrench. Screw one of these on tightly. Turn two vulcanized fiber discs as shown at "b" in Figure 7, and slide one on the brass tube; set the segments into the grove; put on the other disc, and screw on the other nut, but be careful not to let the segments get "skewed" or strained into a spiral.

Provision must now be made for getting electrical connection between the segments and the wires that are to be wound on the armature. Insert an arbor in the commutator and tilt it on a wooden jig or frame to an angle of about 15 degrees. Prick-punch into the fiber in sixteen places opposite the centers of the segments, and drill through the fiber with a No. 32 drill; then continue through the segment with a No. 40 drill, and thread with a 4-36 tap. Brass rods, threaded 4-36, "e" Figure 4 may be screwed into these holes, care being taken not to let them extend through the segments and touch the tube. Bind some copper wire tightly around the segments to hold them in place, and remove the nut from the end farthest from the connection screws; take off the disc and clean out the chips of copper that may have collected. Reassemble the parts, remove the binding wire, and turn the surface of the segments even, finishing with a piece of fine sand paper.

Brushes, Holders and Yokes. Two kinds of brushes are commonly used, copper and carbon, with appropriate holders.

The same supports called "yoke and studs" will fit either. For the former, "planished" or hard rolled leaf copper about five-one-thousandths inch thick is to be cut in strips seven-sixteenths inch

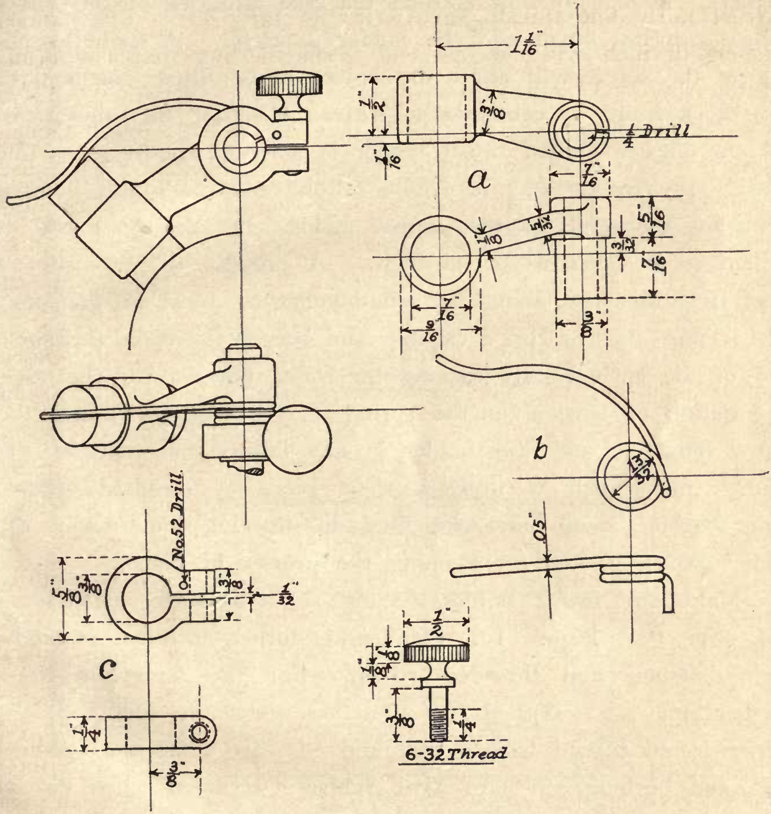

FIGURE 9.

wide and two inches long. Enough to equal one-eighth inch thickness should be grouped together and soldered at one end, the other bevelled to an angle of 45 degrees, to fit the commutator. The holder is shown assembled and in detail in Fig-

ure 8. There are two brass castings, a body "a" and shoe "b"; a clamp "c" of sheet copper, and thumb screw "d" of brass. The construction is such that the pressure of the screw binds both the brush and the holder securely. A slight loosening of the screw will allow the holder to be tilted, and remove the brush from the commutator, without changing the adjustment.

A suitable carbon brush holder is given in Figure 9. The brass body casting "a" is drilled at one end one-fourth inch in diameter, the same as the copper holder, but the other end is drilled seven-sixteenths of an inch. A presser "b" is made of steel or brass wire about five one-hundredths inch in diameter. The clamp "c" is also a casting, and serves to retain the short end of the spring. By turning the clamp one way or the other a variation of tension on the spring may be obtained, and the screw binds it and the holder in any desired position on the stud. The brush is itself a short piece of standard electric light carbon, with one end filed to fit the commutator the other with a groove for keeping the presser in place.

Make the brush holder "studs" of one-fourth inch brass rod. See "a" Figure 10. One end is turned to three-sixteenths inch diameter and threaded 10-24. For the flange, a brass washer may be slipped on the three-sixteenths inch portion, soldered and turned true. "b" and "f" are brass, the washers "c" and bushing "d" are hard rubber; terminal clip "e" is sheet copper.

It is necessary to provide some means of adjusting the position of the brushes. This is accomplished by attaching the studs to a rocker or "yoke." The construction is shown also in Figure 10. Bore out the center of the casting to fit on the turned portion of the bearing as previously noted; drill and tap

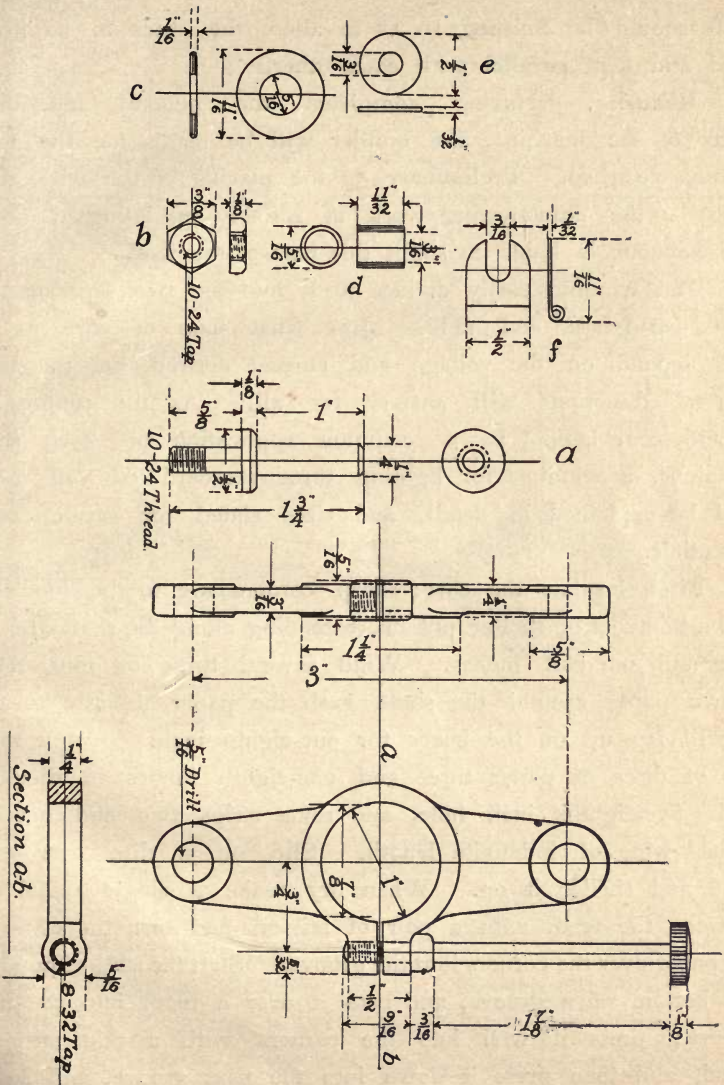

FIGURE 10.

for the thumb screw, and then saw the slot. The rounding ends should be finished so as to allow the studs to be firmly held and kept parallel with each other.

Winding. Having completed the general mechanical parts of the machine, the builder will be ready for the more purely electrical. Preliminary to the placing of the wire, there must be the uninteresting work of suitably insulating the core. An amateur is liable to slight this part of the work.

The winding easily divides itself into the two separate portions,—armature and field. Just what sizes of wire to use will depend on the voltage and current desired, but the same general directions will answer for all. As the running of incandescent lamps is a common application of even small dynamos, a winding for lighting three standard 50 volt lamps will be explained in detail, and sizes stated for various other potentials.

First, insulate the core; sharp corners are to be filed off, and a thin coat of shellac put on, extending along the shaft also for one and one-half inches. Wind several turns of thin, tough brown paper around the shaft, gash the paper a little so that it will lap up on the heads for one-eighth inch. Cut a number of discs of paper three and one-eighth inches in diameter with five-eighths inch hole, and some strips two and one-half inches wide of indefinite length. Slip on a disc over each head and shellac it on. When dry make a single radial cut between the teeth with a pair of scissors and turn the edges of the paper over the corners into the grooves. Start the strip of paper in the bottom of a groove, and pass it over a tooth into the next groove; press it well into the corners with a thin strip of wood, and then press it down into the next groove, and so on

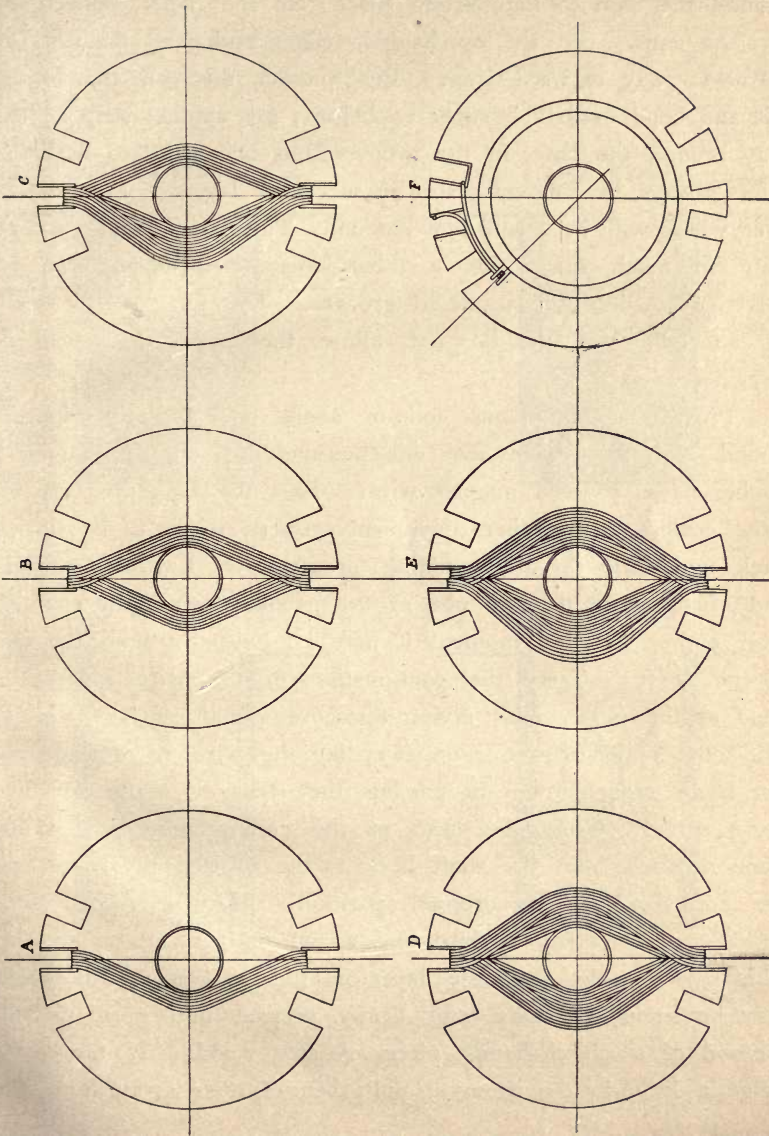

FIGURE 11.

around the core to the starting place; cut the paper, but do not lap the ends. Slit the overhanging edges and bend them so as to cover any exposed iron. Put another disc on the heads, slit and bend over their edges as before; put another strip all the way around the core, in the grooves, but be careful to have the joints always in different places in successive layers. Four layers everywhere will be a sufficient amount. The paper should occupy only so much space that a three-sixteenths inch strip can be forced down into the insulated grooves. Use thin shellac freely as an adhesive and do not allow the paper to "pucker" anywhere.

Provide a continuous coil of about one and three-fourths pound No. 22 (twenty-five one-thousandths inch in diameter) double cotton covered magnet wire. Rest the armature between lathe centers or on other convenient support, so as to be turned back and forth as the winding progresses. Lay the starting end of the wire through one of the grooves toward the commutator end. For the moment it may be twisted around the end of the shaft. Carry the continuation of the wire across the head at the pulley end, giving the core a half turn so as to bring the opposite groove on top; lay the wire in this groove but leave enough room in passing the shaft to allow for five more turns. Cross the head at the commutator end, at the same distance from the shaft back to the starting point, rotating the core back to its original position. Lay a second turn beside the first, then a third, and so on until six turns are on. This should make just one layer in the grooves. The wires may be smoothed down and firmly pressed into position with the aid of a chisel-shaped piece of soft wood. If the wires bulge a little in the grooves, pull them further away from the

shaft, thus drawing them tight in other places. If sufficient room has not been allowed to get all the turns in past the shaft, a little stretching of this kind may provide space. Shellac these six turns and let them dry. "A", Figure 11, shows this

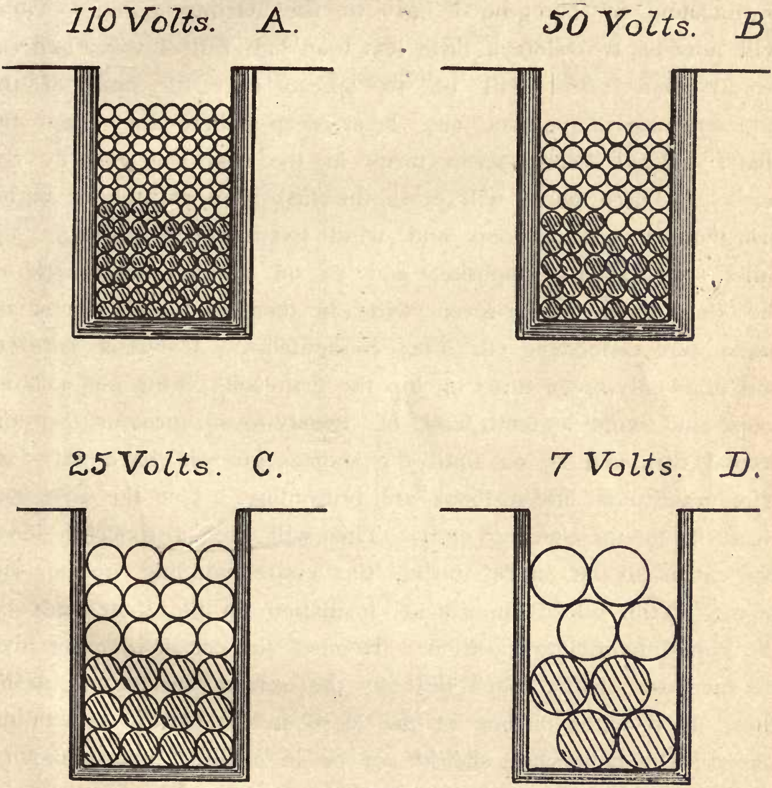

FIGURE 12.

first layer. Continue the winding in a second layer, and place six turns on the other side of the shaft. "B", Figure 11, shows this stage. Shellac again and when dry, wind on a third layer of six turns, passing the shaft on the same side

as the first layer, only further out. See "C" Figure 11. A fourth layer goes on the other side, as shown in "D", and also a half layer of three turns,—"E". Make a loop in the wire about three inches long, twist the two together and lay the continuation in the groove next to the starting point. There will now be two slots a little less than half full of wire, and the twenty-seven turns will be so spread over the ends of the armature as to be but one layer deep where they pass the shaft. Wind twenty-seven turns in the next slot and its opposite. These wires will cross the first wire at a slight angle; bring out a second loop and wind twenty-seven turns in the third slot and its opposite, and so on around until each of the slots have twenty-seven wires in them and eight loops are made for connecting to the commutator. Continue a ninth coil of twenty-seven turns on top the first coil; bring out a ninth loop, and wind a tenth coil of twenty-seven turns on top the second coil, and so on until the sixteen grooves have fifty-four wires each and fifteen loops are protruding. Cut the wire and twist it to the starting end. This will give a sixteenth loop. No cut is to be made during the entire winding up to this point. Trim off all superfluous insulation on the shaft and slip the commutator into position. Remove the cotton covering from the portions of the loops next to the screws in the segments. Insert both wires of one of the loops in the slot in one of the screws; this connection should not be in a direct axial line, but carried to the second segment beyond, in the direction of rotation. See "F", Figure 11. Solder the wires in position. Bring the second loop to the next segment, and so on until all have been connected. The appearance will then be as if the commutator had been given one-eighth of a turn after the wires

had been connected. The object of this advance, or "lead", is to bring the brushes in a more convenient position. Shellac the connecting wires to prevent unravelling of the insulation. Remove the paper from the surface of core so that the ends of the sheet iron teeth will be exposed. If the winding has been carefully done and tightly pressed in place, no binding wires will be needed; but if desired, a place about one-half inch

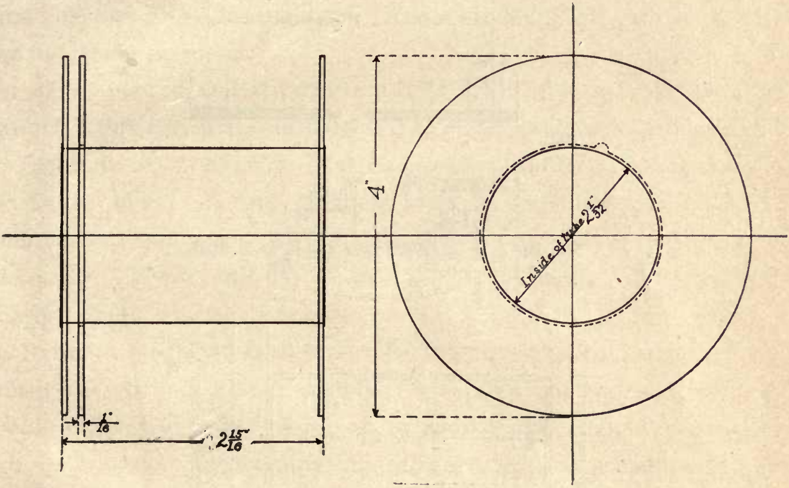

FIGURE 13.

wide may previously have been turned in the center of the core to a diameter of two and fifteen-sixteenths inches; strips of thin mica may be laid over the copper wires for extra insulation, and this space tightly wound with fine brass wire. Solder the wires together before loosening the tension.

It is common practice among manufacturers of dynamos and motors to cover the exposed ends of the armature with conical "dressings" of canvas. The amateur may not feel inclined to bother with this.

Other windings may be:—Seven volts, suitable for plating, can be obtained by using No. 13 (seventy-two one-thousandths inch diameter) wire. Two turns will make one layer, and two layers put in each slot for each half winding, and loops brought out as usual and four turns wound in the next slot. "D" Figure 12

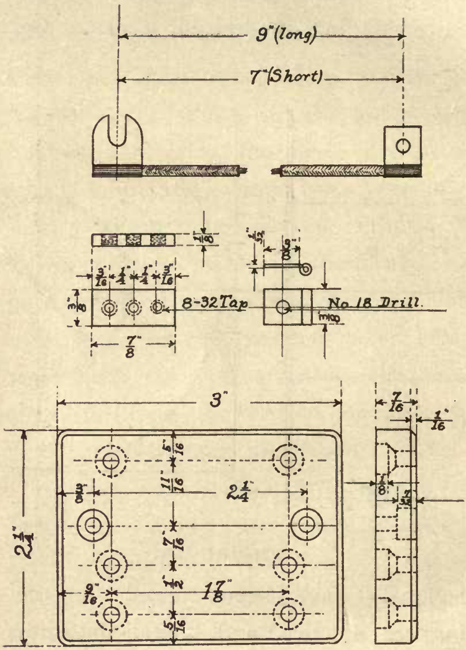

FIGURE 14.

shows the eight wires, the blackened ones representing the four turns of the first half-winding, the light ones showing the wires of the last half. This wire will allow an output of thirty amperes, and copper brushes of extra thickness should be used.

Twenty-five volts. This is a suitable potential for a motor using batteries for a source of current. Use No. 17 wire (forty-five

one-thousandths inch diameter). Put four turns per layer, three layers deep for each half-winding. See "C" Figure 12. It may be necessary to use slightly thinner insulation in the slots in order to get the wire in, but the potential is so low that there would be no danger of "ground" or "short circuit." In crossing the heads, let six wires be on one side of the shaft, and three on the other, in regular order. The halves of the winding will then balance the inequality. This winding will allow a current of eight amperes.

One hundred and ten volts. It is practicable to wind an armature for this potential, but special care and considerable patience will be required. No. 26 wire (sixteen one-thousandths inch diameter) is wanted. Wind six and one-half layers, eight turns per layer for each half winding. "A", Figure 12, shows the arrangement in one slot. There will be 52 turns per segment. The current capacity will be two amperes.

Higher voltage should not be attempted in so small a machine, as the excessive number of turns of wire introduces the insulation so many times as to reduce the amount of copper below its safe current-carrying capacity. An armature would last so short a time as scarcely to repay the builder for his trouble.

Field Winding. In consequence of the round core of the field magnet, this winding can be quickly done in a lathe. Figure 13 shows a detail of a spool. It consists of three leatheroid or fiber discs four inches outside diameter, the two outer ones having a hole two and one-sixteenth inches diameter, the inner one two and one-eighth inches. A tin or other thin sheet metal tube, soldered along its lapped edge, and rolled with a small flange at the ends, holds the discs in position. For winding,

the spool may be slipped on a wooden arbor with check-pieces or flanges to keep the discs from spreading by the crowding action of the wire.

Wind four or five layers of paper around the tin tube, duly shellacked. The edges of the paper can be pressed under the loose disc and lapped onto the others. Put the starting end of the wire through the notch, and draw through a considerable length depending on the size used. Wind one turn of this end length backwards around the spool and coil the rest around the arbor. Press the loose disc against this one turn, and wind two or three layers in the main part of the spool. By hand, wind two or three turns backwards, from the wire on the arbor. Put a piece of thin paper on the main coil and wind several more layers; give the end wire a few more turns and so on until the requisite number is in place. It will be seen that the object of the extra disc and the long protruding end at the start was to keep the wire leading to the first layer well insulated from the successive ones, and also to leave the inside end so that if accidentally broken off, a turn or two can be unwound without disturbing the main part of the spool.

If fine wire is used the ends may finally be led through holes drilled near the edges of the discs, but large wires can be tied to the discs by string taken through a number of small holes. Leave the ends protruding about six inches. As usual with electrical apparatus, shellac the outside layer.

About fifteen hundred ampere turns are required for field excitation; the particular sizes of wire will depend on the voltage of the armature.

Fifty volts. Series: five pounds of No. 13 wire (seventy-two one-thousandths inch diameter) wound eleven layers deep.

Shunt: three pounds of No. 25 wire (eighteen one-thousandths inch diameter) wind thirty-three layers deep. For a compound field use first two and one-fourth pounds of No. 26 wire (sixteen one-thousandths inch in diameter) twenty-nine layers deep; wrap on a few turns of thin paper, shellac discs of paper over the leading ends of the wires to protect their insulation, and wind, in the same direction, one and one-half pounds of No. 14 wire (sixty-four one-thousandths inch in diameter) three layers deep.

Seven volts. A series field is unsuitable for plating. For shunt use four and one-half pounds of No. 17 wire (forty-five one thousandths inch in diameter) seventeen layers deep. A compound winding may have in the shunt, three pounds of No. 18 wire (four one-hundredths inch in diameter) fifteen layers deep, and in the series one and one-half pounds of No. 6 wire (one hundred and sixty-two one-thousandths inch in diameter) one layer deep.

Twenty-five volts. Series: four and one-half pounds of No. 10 wire (one hundred and two one-thousandths inch in diameter) seven layers deep. Shunt: three pounds of No. 22 wire (twenty-five one-thousandths inch in diameter) twenty-three layers deep. Probably the builder would have no occasion for a compound field for this potential.

One hundred and ten volts. Series: four and one-half pounds of No. 17 wire (forty-five one-thousandths inch diameter) seventeen layers deep. It will be noticed that this is identical with the shunt requirements for seven volts. Shunt: three pounds of No. 27 wire (fourteen one-thousandths inch in diameter) forty-one layers deep.

In each case an odd number of layers has been stated in order

to bring the terminals of the coils at opposite ends of the spool.

Connections. Any kind of seasoned hard wood is suit-

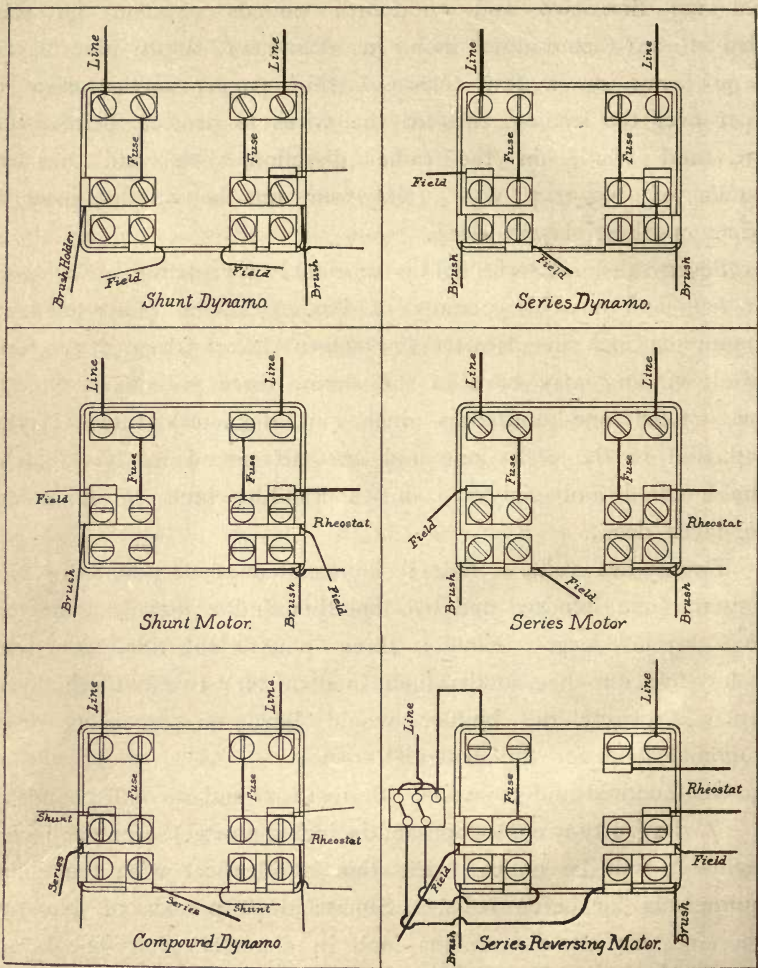

FIGURE 15.

able for the connection board. Finish it in varnish or shellac, and drill as shown in Figure 14. Rectangular brass strips are

to be drilled and tapped 8-32 and attached to the board by screws "f" (Figure 4), inserted through from the back and entering the center holes. The two end screws for each strip "g" (Figure 4) enter the board one-eighth of an inch to prevent "skewing." These holes may be made with a No. 18 drill, after their location has been marked from the strips. Use no shellac on the surface of the brass as electrical contact would thereby be destroyed. Connections are made by soldering sheet copper clips to the wires and clamping them to the blocks. Incandescent lamp cord is suitable for flexible cables to connect the brushes with the terminals. One strand will be sufficient for the current of a fifty or one hundred and ten volt armature, but two strands for the twenty-five volt, and four for the seven volt winding should be used, all soldered into a sufficiently large clip.

By means of this simple arrangement of contact blocks, almost any combination of wires may be made, allowing the machine to be used for a variety of purposes. Figure 15 also shows the necessary wiring for connecting as series, shunt, or compound dynamo; series, shunt, or reversing motor. It is not the purpose of this book to describe switch-board appliances, so locations only of rheostats and reversing switch are shown.

After assembling the machine, the field wires should be straightened, and short pieces of small soft rubber tubing slipped on, so as to insure insulation from the frame.

Testing and Using. The various uses to which the machine is put, and conditions under which it works, will determine just which of the connection board arrangements to adopt.

If used as a dynamo to run incandescent lamps or a plating bath,—the potential controlled by a rheostat in the field,—

use the "Shunt Dynamo" board, or if fairly close automatic regulation is desired, use the "compound" connections. A rheostat in the shunt circuit will still be useful to compensate for variations in speed. When no rheostat is wanted, connect its two points on the board with a short wire.

In starting a shunt or compound dynamo, turn the rheostat until all the resistance is "out," that is equivalent to dispensing with its use. Let the main switch controlling the lamp circuit be "open." Drive the armature at its correct speed, 2600 revolutions per minute. Set the brushes on the "neutral' point,—that is, on segments which connect with coils just half way between the two pole pieces. The correct location is shown in Fig. 1. Let the brushes bear with a firm yet even pressure; lift one of them from the commutator and touch wires leading from a battery, or other source of continuous current, to the field terminals. This is to put some initial magnetism into the iron. Remove the battery wires and replace the brush. Move the yoke slowly back and forth; if current is being generated, sparks will appear at the brushes, and strong magnetism be felt at the poles. For use, keep the brushes on the neutral point, which is the position of least sparking, indeed there may be an entire absence of that evil. If no current is generated, remove the screws holding the cable terminals and exchange their location by connecting the long one where the short one was. The dynamo should now generate. Always allow a few minutes for the machine to "build up," so called. A shunt dynamo is often very sluggish in starting. Now connect the lamps by closing the main switch, turning the rheostat if necessary to adjust the potential. Safety fuses of standard make should be used as shown. In case of overload, or

accidental short-circuit, the fuses melt and save the armature from " burn out."

For starting a compound dynamo,—the same method may be used, with the additional precaution to observe that the current in the series coil must be in the same direction as in the shunt; otherwise its influence would be to oppose instead of help the regulation.

A series dynamo is suitable for running an arc lamp,—in this case a small one,—and for general experimenting. Adjust the brushes and connect a battery to the line terminals. The armature will try to run as a motor; if it tries to turn against its brushes, remove the battery wires, connect the line, and drive the armature in the direction of its brushes; the dynamo should now generate. If, when the battery is connected, the armature turns *with* the brushes (in the direction in which they point), reverse the cables leading from the brush holders. Driven in its proper direction again, the armature should generate.

Three cases as a motor need to be considered. If uniform speed is desired, independent of the load, a shunt field should be used. If current is supplied from a constant potential circuit, a rheostat must be connected in the armature circuit to prevent an over-current. Turning the main switch will allow the fields to get magnetised, but the armature current has to travel through the rheostat. As the speed increases, turn the resistance out. If the armature tries to run in the wrong direction, reverse the brush holder cables. If primary batteries are the source of current, the gradual lowering of the zincs into the acid will obviate the necessity of a starting rheostat.

For variable speeds a series motor is required; a rheostat

will still be necessary for use on constant potential mains. A series motor will always run at a constant speed if the load is constant; hence it is common to put series windings on fan motors because of cheapness. If used to drive a fan a collar should be put on the pulley end of the shaft to run against the lining and receive the "end thrust," the regular shoulders being insufficient for so much pressure.

Besides the ability to run at various speeds, a "reversible" motor is sometimes desired. One line wire (Fig. 15) leads to the connection board, the other to the reversing switch, which is shown in diagram. The circuits are such that the fields are always magnetised with the same polarity, but the direction of the current through the armature is reversible by moving the two parallel fingers of the switch. The reversal of a motor is accomplished by changing the current through either field or armature,—not through both. A starting rheostat is also included in circuit; one of the fuses is omitted in order to make the connections more convenient.

Regular sizes of fuses should be,—for the one hundred and ten volt winding, three amperes; this is the smallest size made. For fifty volts, four amperes; for twenty-five volts, eight amperes; and for seven volts, thirty amperes capacity.

If the builder has followed the directions carefully the machine will work to perfection,—it cannot help it. This dynamo is suitable for a variety of practical uses, not the least of which may be as "exciter" for the fields of a small alternator. As a motor, it will run a fan, several sewing machines, or small lathe. With success assured from the small outlay thus required the builder may properly attempt the construction of larger machines.

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